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VOLUME II NUMBER 2 25 FEBRUARY 1963

SPECTROSCOPY OF TWO-ELECTRON ATOMS

EDMUND P. GAINES, JR., Major, USAF, General Physics Division (AFOSR)

A new and powerful method of solving the energy equation of two-electron atoms has been developed by Professor C. L. Pekeris of the Weizman Institute in Israel as the result of research supported by AFOSR. Professor Pekeris' method deviates from the classical variational procedure of calculation in the choice of novel mathematical relations which define the position of the electrons with respect to the nucleus. Use of this new set of variables, called perimetric coordinates, permits exact solution of the energy equation for two-electron atoms, provided tedious calculations can be performed. These calculations can involve more than 1,000 equations each having more than 1,000 terms. (In the case of helium, the ionization potential for the $1s^2\ ^1S$ state was calculated with an error of 1 part in 3×10^9 from the solution of a determinant of order 1,078). Although it may be suspected that modern high speed computers are capable of performing such complex computational feats, it is, nevertheless, amazing that problems involving computations of this magnitude can be correctly prepared and solutions obtained by any technique, however mechanized.

By this method, Professor Pekeris, early this year, predicted theoretically the wave length of radiation from a certain energy transition ($1s2s\,^1S - 1s2p\,^1P$) of singly ionized lithium (Li^+). He reported that this radiation should have an uncorrected wave length of about 9,584 angstroms (an angstrom is $1/10^8$ centimeters). Recently, Y. G. Torreson and B. Edlin reported experimental detection of this transition at 9,581.42 angstroms, which is in complete agreement with Professor Pekeris' theoretical prediction when certain corrections (mass polarization, relativistic, and radiative) are made to his result. Earlier investigators had identified the $1s2s\,^1S - 1s2p\,^1P$ transition in Li^+ with the 8,517.4 angstrom spectral line. Thus a correction, equivalent to the difference between blue and yellow light in the visible spectrum, has been made to data concerning the structure of ionized lithium. This important contribution to our understanding of atomic physics demonstrates the power and

precision of the method developed by Professor Pekeris. It also is a classic example of how theory and experiment must support and confirm each other to produce reliable scientific results.

Professor Pekeris is currently studying negatively ionized hydrogen (H^-), helium, and singly ionized lithium. Studies of two-electron atoms are of considerable interest to astrophysicists and to atomic physicists in general. Of particular interest to astrophysicists are studies of the negative hydrogen ion. Absorption by this atom is thought to be the principal mechanism of opacity in the solar photosphere. After he completes his studies of the two-electron atoms, Professor Pekeris plans to direct his efforts towards solution of the nuclear three-body problem, using techniques which are the outgrowth of his current program. Solution of this problem would be of the greatest importance to nuclear physicists in the development of a general theory of nuclear forces.

FOCUSING ENERGY OF SPHERICAL REFLECTORS

PHILIPP BLACKSMITH, JR., Electromagnetic Radiation Laboratory (AFCRL)

Good results have been obtained by AFCRL with an experimental feed mechanism designed to correct the focusing of spherical antennas of the Arecibo type. Within coming weeks, AFCRL may recommend that such a feed be developed for use with the Arecibo telescope. The AFCRL Gregorian-type feed has several advantages over Arecibo's line source feed. Foremost is its broadband features which extend from about 430 Mcps out beyond 1400 Mcps and thus encompasses the important hydrogen line region (21 cm).

AFCRL research into the correction of spherical reflectors has a history dating back to 1949 -- and it was this history that resulted in the assignment to AFCRL by ARPA of management responsibilities for the Arecibo telescope. When Cornell University's proposal for the 1000-foot Puerto Rican radio telescope reached AFCRL for technical evaluation (in 1959), AFCRL enthusiastically endorsed the concept -- but made one basic design change. Where Cornell initially recommended a parabolic reflector, AFCRL suggested that a partial sphere be used instead. The advantage of the spherical reflector over a parabolic reflector, when both are fixed and scanning must be done by feed rotation, is that the spherical antenna can be scanned over a great angle.

Spherical reflectors, unlike paraboloids, do not focus the reflected energy to one point. All rays from the surface of a spherical reflector intersect the central axis. There are several techniques

for overcoming the focusing problem -- multiple point sources, phased line sources, correcting reflectors, and correcting lenses. AFCRL, over a number of years, has investigated all of these. For the Arecibo telescope, the phased line source technique was recommended.

In this feed, the incoming energy is collected through slots in a long waveguide suspended along the center axis. The energy is channeled through this waveguide feed to a common point. The Arecibo feed is some 90 feet in length and weighs about 5 tons. A major disadvantage of the Arecibo feed is that operation is narrow band with a center frequency of 430 Mcps.

The modified Gregorian feed, largely developed by Sheppard Holt of AFCRL, consists of a dish-shaped auxiliary reflector facing the larger primary reflector and an associated feedhorn. Rays from the primary reflector are collected by the auxiliary reflector and redirected so that they come together at a common point. The feedhorn is located at this point. The precise shape of the auxiliary reflector is determined by ray path considerations. Parameters involved in the solution are the radius of the primary reflector, the location of the auxiliary reflector, and the position of the feedhorn with respect to the auxiliary reflector.

AFCRL's experimental model of this Gregorian feed was operated with a 10-foot reflector. The Gregorian correcting feed of this model measured about 15 inches across. Highly successful tests were conducted on both X- and K-bands. The Gregorian feed -- that is, the auxiliary reflector and the feedhorn -- move as a unit to scan. As this corrector feed moves, different sections of the reflector are illuminated.

The proposed Arecibo feed would measure 35-feet across, scan a 40-degree cone, and would illuminate a 600-foot diameter portion of the 1000-foot reflector. A minor disadvantage is that the spherical Gregorian system is aperture-blocked in two different ways. The aperture of the spherical reflector is blocked by the correcting reflector and the aperture of the correcting reflector is in turn blocked by the feedhorn. Less than two percent of the energy of the primary reflector, however, would be blocked in this manner.

If used with the Arecibo dish, the reflector would be positioned some 435 feet above the reflecting screen. It is not considered as a replacement for the present line source feed, but as a supplemental feed, permitting operation of the dish at higher frequencies.

phase transformations in solids

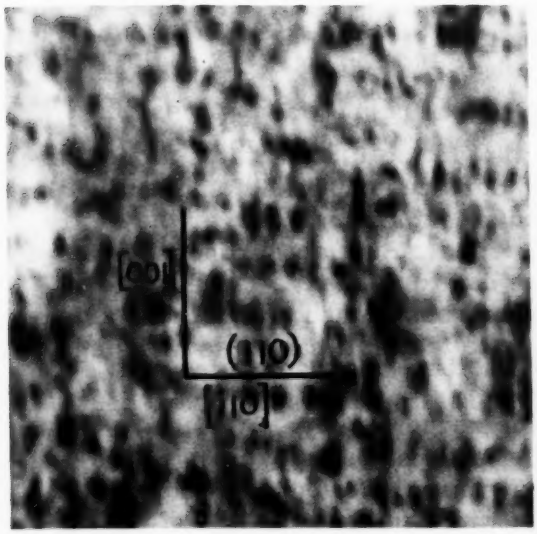
LT. COLONEL RALPH W. CONNERS, Solid State Sciences Division (AFOSR)

Work at Northwestern University under Contract AF 49(638)-524, "Phase Transformations in Solids," has shown that in many precipitation hardened systems, such as Ni and Al base alloys, at the stage of optimum mechanical properties the precipitates are so profuse that they must be cut during plastic deformation. Slip dislocations must pass through the precipitates rather than around them and this is an important source of the strengthening. This has been directly demonstrated by changes in magnetic properties in Ni-base alloys (Nimonic and Inconel alloys are Ni-base alloys). The strength is determined by the maximum barrier presented to the dislocation and thus certain periodic arrangements of precipitates will present a stronger barrier than a random arrangement. This may be the key to the development of improved alloys by people in applied research organizations.

In certain Ni-base alloys, the precipitates are arranged periodically in two directions, as shown in the accompanying transmission electron micrographs. Note that the small period is parallel to the Burgers vector of the dislocation or slip direction. It is suggested that precipitate aging of alloys under applied stress or in a magnetic field (if the alloys are ferromagnetic) be tried to see if desired periodicity of precipitates may be obtained.

Alloying and heat treatment of ceramics to obtain improved properties is a field which is in its infancy. For example, increased strength may be obtained by causing fine precipitates to be present. In NaCl, which has the same crystal structure as MgO, small KCl-rich precipitates increase the compressive strength for fracture by a factor of at least 7. This is most likely due to an increase in the fracture path, since cleavage is not continuous through the precipitate particles. Thermal shock resistance may very likely be improved in this way.

Electron Micrographs of Phase Transformations in an Age-hardened Nickel-Titanium Alloy



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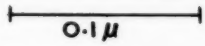

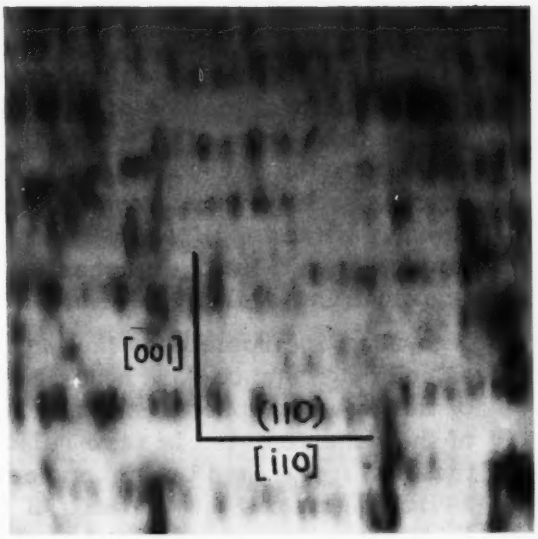

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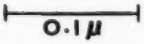


Nickel based alloy containing 10 atomic percent of titanium, initially heated to 100^0 for ½ hour to dissolve the titanium into the nickel. When the solid-solution of titanium in nickel was completed the alloy was quenched to minus 260 ^{0}C reheated to 700^{0}C for 5 hours in photo A and for 10 hours in Photo B, annealed to room temperature. The dark particles in the electron micrographs are the Ni_3 Ti precipitates resulting from the phase transformation. Note that in A the metallic precipitates are distributed slightly parallel to the (001) crystalographic direction whereas in B the additional 5 hours of ageing-heat treatment produced larger-sized precipitates and a higher degree of orientation. The enlarged, oriented precipitated phase in the nickel based alloy makes it a much stronger material for structural engineering uses.

airborne survey of natural landing areas

CARLTON E. MOLINEUX
Terrestrial Sciences
Laboratory (AFCRL)

Air Force scientists estimate that in the United States alone there are several hundred open, flat land surfaces capable of supporting the landing weight of a fully-loaded modern jet aircraft. Over the entire earth, there are thousands of such areas. But soil hardness varies from season to season and from one day to the next. Once a likely spot for an emergency landing field has been found, it becomes an expensive and time-consuming process to test soil hardness by using ground-based survey teams.

To overcome these problems of ground surveys, AFCRL has devised a novel method of measuring soil hardness by using a projectile fired from a high-speed jet aircraft. Called an airborne penetrometer, the one-pound device is carried in the wing tips of the aircraft. Each penetrometer is loaded into one of five cannons mounted in each of the modified tip tanks. As the aircraft flies over a potential landing area a timing mechanism fires the penetrometers at predetermined intervals.

The penetrometers, having an appearance of small rockets, are aimed down and back at a horizontal velocity sufficient to cancel that of the forward speed of the aircraft. The resulting horizontal velocity of the penetrometer is zero relative to the ground. The depth of penetration is governed by the degree of soil hardness. A decleration switch measures the impact. If the impact is greater than a pre-set level, an infrared bulb in the tail of the penetrometer lights up. Thus each individual penetrometer measures only whether or not the soil-strength is greater than a given predetermined level.

The penetrometers may be released at any altitude although optimum release altitude appears to be about 1000 feet. Once the penetrometers have been fired, the aircraft may then circle back and take infrared pictures of the penetrometer's impact area -- or a second, following aircraft may take the infrared photographs. The technique may prove of value not only for Air Force operations but also as an emergency measure for commercial airliners.

AUTOMATIC STORM OBSERVATION SYSTEM

DR. DAVID ATLAS
Meteorological Research
Laboratory (AFCRL)

Recently placed in operation at AFCRL is a new weather radar data processor which, because of its speed and special capability may revolutionize methods of short range storm observation and forecasting. Initial tests of the system in tracking a tornado in Eastern Massachusetts have already demonstrated the system's effectiveness. The data processor was designed on the basis of techniques originally developed by Dr. David Atlas of AFCRL.

The data processor, called STRADAP (for Storm Radar Data Processor), is tied directly to a conventional weather radar. While the radar scans the skies, the data processor measures the intensity of storm echoes at various altitudes within each square mile of geographical area. After 18 revolutions of the radar antenna, the processor automatically prints out two numerical maps. One is a geographical configuration of the storm reflectivity, composed of numbers ranging from one to seven (light rain to severe and dangerous storms). Each number represents the maximum storm intensity in each 25-square mile sub-sector of the storm. The other map is a similar array of numbers, each representing the maximum storm height in each of the 25-square mile sub-sectors. The latter is literally a topographic map of the storm.

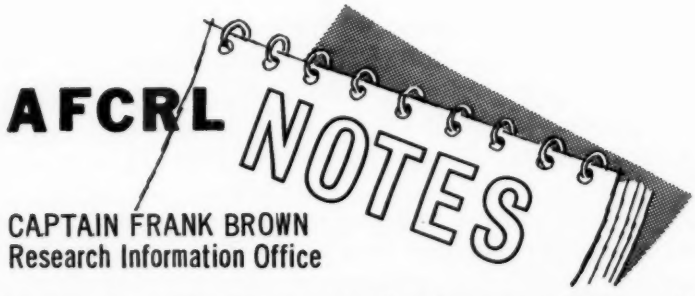
Since these maps are available every few minutes, the meteorologist can detect changes in a storm situation rapidly and accurately, and can pay particular attention to those areas where the most severe activity is developing. The radar beam scans a radius of about 120 miles in consecutive rotations -- first at zero degree elevation, then one degree, two degrees, and so on, until 20 degrees of elevation are covered. This scanning program takes about three and one-half minutes. During this time, radar echo reflectivity in each square mile is measured at a pre-selected height above the earth's surface. The processor compares 25 such measurements in a 25-square mile square sector, and stores only the strongest single echo in its memory. Only the strongest return of the 25 is printed on the storm map. Since the echo intensity from a target of given reflectivity decreases

with distance, the computer automatically corrects for the distance from the radar to the storm. At the same time, the computer remembers the maximum height of the storm echoes in each 25-square mile sector.

A basic feature of the system is an automatic alarm. This alarm can be set to go off if either the intensity or the height, or a combination of both, exceed preset critical values. The machine can thus be left unattended. When placed in full operation, information can be transmitted over standard telephone lines to remote printers so that all airfields within a given radius of a storm can receive the data immediately.

A network of approximately 100 long-range radars and data processing units could provide automatic storm mapping for the entire nation. A complete nation-wide storm map could be compiled in about 30 minutes. This would allow an entire national storm display to be updated two times an hour in rapidly developing situations.

The AFCRL system was financed under the 433L Weather Observing and Forecasting System of the Electronic Systems Division (AFSC). The data processor was built for AFCRL by Budd Electronics.



CAPTAIN FRANK BROWN
Research Information Office

Under its Project Firefly III chemical release program, AFCRL made a total of 65 chemical releases in the atmosphere between 90 and 300 Km during the period 15 October to 15 December. Twenty-seven of the 33 rockets scheduled under the program were fired successfully. The multi-phased study was conducted to investigate propagation effects, wind characteristics, temperatures at extreme altitudes, and electron removal by chemical means from the E and F regions. One of the more interesting experiments was the creation of a large 10 by 30 Km hole in the F-layer by means of the release of sulfur hexafluoride at an altitude of about 250 Km. The electron de-

pleted region lasted for 30 to 40 minutes. As a result of the FIREFLY experiments, a number of techniques were demonstrated which may prove of great interest for further research into the upper atmosphere and which may have potential value in Air Force operational systems. A preliminary report on the Firefly experiments has been prepared. (Space Physics Laboratory)

A nine-foot diameter inflatable sphere was released an an altitude of about 160 miles in an experiment to determine atmospheric density. The sphere was carried aloft in an Aerobee rocket fired from the Eglin Gulf Test Range during the week of 21 January. Approximately 79 seconds after the rocket was launched the inflatable sphere containing accelerometers was released from the rocket. The accelerometers, measuring the rate of fall, indicated the air densities at various altitudes. Information was telemetered to the ground. (Space Physics Laboratory)

During the December-February period, AFCRL is conducting three distinct balloon astronomy experiments. The first of these, conducted on December 13-14, was Project Stargazer which was widely reported in the public press. This project consisted of carrying two human observers to an altitude above 80,000 feet for making observations of the stars and planets from a 12-inch telescope. Good data were taken. The excellent condition of the telescope and gondola, when recovered, will allow a second Stargazer flight which is now under consideration... Project Sky Top, scheduled for January, was designed to carry a 12-inch telescope to altitudes about 100,000 feet for the purpose of measuring the surface temperatures and atmospheric composition of Mars and Venus. Project Sky Top is an unmanned effort. Several previous flights of Sky Top have already been conducted with varying degrees of success... The third balloon astronomy experiment is Project Balast. Unlike Sky Top, which is largely an in-house AFCRL effort, Project Balast is being instrumented by Johns Hopkins University under AFCRL contract. Project Balast is also an unmanned effort, with target acquisition and data collecting performed automatically. This project is designed to search for evidence of water vapor, carbon dioxide, and other gases in the atmosphere of Venus. The temperature and heat balance of the planet may also be studied. Balast is scheduled for launch in early February and will carry a 12-inch telescope to a maximum altitude of about 85,000 feet. All three of the AFCRL balloon astronomy experiments will be launched from Holloman AFB in New Mexico. (Research Instrumentation Laboratory)

new *HYPERSONIC* wind tunnel air supply

LT. ARTHUR J. WENNERSTROM, Fluid Dynamics Facilities Laboratory (ARL)

One of the problems in the laboratory simulation of hypersonic flow at altitudes as low as 200,000 feet is the creation of truly representative steady flow stagnation values of temperature and pressure. Stagnation pressures as high as 4,000 psi have been attained using high-pressure air bottles, and stagnation temperatures in uncontaminated air up to 4400°R have been obtained with pebble-bed heaters. However, real duplication of these "low-altitude" hypersonic conditions within the permissible flight corridor requires total pressures above 100,000 psi and total temperatures above 10,000°R.

A novel method for achieving these extreme conditions has been proposed by Professor Antonio Ferri of the Polytechnic Institute of Brooklyn. His concept, known as the Mechanical Accelerator, is the subject of an Air Force research contract sponsored by ARL with his institute for exploring the technical feasibility of the device. The Mechanical Accelerator is basically a multistage, axial-flow compressor operating at very high Mach numbers. Flow enters supersonically with a relative Mach number of about 4 and is continuously accelerated through a series of counter-rotating rotors to a Mach number of 10 or more at the exit. By virtue of the high Mach numbers throughout the machine, the static pressures remain low, eliminating the containment problem. For the same reason, static temperatures remain low in the main stream, preventing dissociation and recombination before the tunnel test section. The rotors employ highly cooled, high-solidity blading with very high turning angles on the order of 120 degrees.

The present test program involves cascade tests of appropriate blading designed for and tested at Mach numbers of 3, 4.4 and 8. Studies are being made of heat transfer, pressure recovery, and boundary-layer separation on the cascades in the PIB hypersonic facility. Results to date have indicated that flow can be turned supersonically through angles of 120° with satisfactory pressure recovery, and that the heat transfer to the blades is within controllable limits. The initial phase of the program will culminate in the design of a test compressor. Later phases of the program cover construction and testing of an experimental machine. If future theoretical and experimental results continue to look as promising as those obtained to date, the Mechanical Accelerator promises to offer a really significant advance in the capabilities of hypersonic wind tunnels.

NEW MICROCIRCUIT UNITS

DR. HANS ZSCHIRNT
Computer and Mathematical Sciences Laboratory (AFCRL)

Microcircuit technology has made a major advance with the development by RCA under AFCRL contract of a new solid state element combining properties of transistors and vacuum tubes. The new elements can be produced in large interconnected arrays which have shown unusually consistant performance and reliability. Progress toward operational microcircuit elements has heretofore been retarded because of problems in obtaining uniform performance from unit to unit.

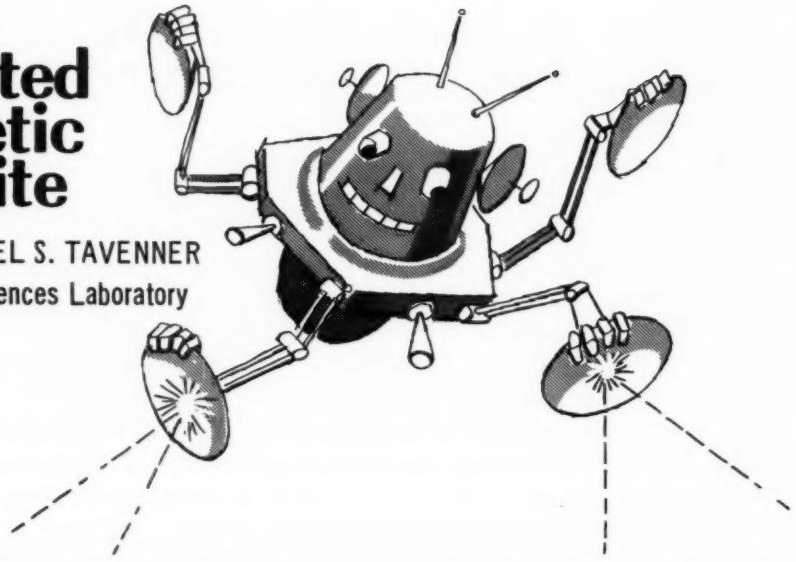
The RCA unit is an insulated gate, field-effect silicon transistor. It is distinguished by an extremely high input impedance coupled with low input capacitance. It also lends itself readily to direct coupled circuitry. Its operational characteristics have great simularity to those of a pentode vacuum tube. By varying the input voltage on the insulated gate, the device as a whole can be made to switch, amplify or otherwise regulate its output of electric current in a manner analogous to a pentode vacuum tube. In conventional transistors, similar results are achieved by making changes in the magnitude of the input current.

Complex arrays of up to 850 of the new components have been produced in an area the size of a dime. Circuits built from these arrays include amplifiers and electronic switches and counters for computers. The elements can operate within a temperature range of -80 to 190 degrees C, and have a switching speed of 10-20 nanoseconds. These switching speeds compare with those of high speed cryogenic elements. The compactness of the array and the very short interconnections would result in switching circuits with a much greater speed than is possible in computers made up of conventional arrays.

AFCRL is sponsoring research in a number of industrial research laboratories concerned with techniques for the design and fabrication of microcircuits. Many different fabrication techniques are under study. The RCA element will be subjected to a great variety of tests by AFCRL scientists.

laser activated geodetic satellite

CAPT. MICHAEL S. TAVENNER
Terrestrial Sciences Laboratory
(AFCRL)



Within the past year, increasingly precise knowledge of the distances between major land masses has been obtained. Much of this geodetic knowledge has come about by the technique of photographing a brilliant light source at high altitudes against a stellar background. If simultaneous photographs are taken from at least two camera sites whose position is known the position of the light flashes in space can be determined. Then by using other cameras at sites whose positions are relatively unknown, the positions of these unknown sites can be determined by geometrical triangulation.

Two AFCRL geodetic experiments conducted during the past year contributed to our increasingly precise geodetic knowledge. The first involved, the release of brilliant flares by rockets at extreme altitudes. The second, and better known experiment, involved the satellite ANNA in which AFCRL played a major role. Each of these methods has disadvantages. The rocket flare method, although relatively inexpensive, is a "one-time" shot. A flashing light on a satellite such as ANNA is complex, costly, and has a limited lifetime.

In a paper recently prepared by Captain Michael S. Tavenner of AFCRL, a technique is discussed which will overcome the disadvantages. The system essentially consists of placing a simple, passive reflecting satellite in orbit and using a ground-based laser as a light source for reflecting a signal off the satellite. AFCRL has recently begun to evaluate various techniques for possible use on the satellite,

and is in the process of acquiring a ruby laser with sufficient energy to illuminate the satellite.

In this technique, lasers, located at several ground observing stations, beam light pulses activated by a common triggering circuit to the satellite. The satellite reflects each signal back to its respective source where the light is photographed against a background of stars.

The laser system has a number of advantages: 1) all complicated equipment is on the ground where it may be repaired or adjusted, 2) by keeping the reflectors small, weight will be held to a minimum, 3) power requirements for the source are small, and 4) the system is adaptable for tracking any satellite or missile.

It is not, of course, necessary that a special, reflecting satellite be used. Reflectors can be attached to a variety of satellites. The reflectors will have greatest efficiency, however, if the laser beam is reflected back to its point of origin, parallel to the incident beam. Captain Tavenner, in his paper, examines two such reflectors, both of the corner reflector type in which the light is reflected against three mirrored surfaces before the beam returns to its source.

PROPAGATION OF ACOUSTIC-GRAVITY WAVES IN THE ATMOSPHERE

WILLIAM J. BEST, Major, USAF, Directorate of Physical Sciences (AFOSR)

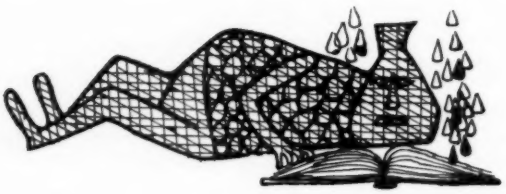
Interest in the problem of the propagation of a pulse in the atmosphere began when world-wide pressure disturbances were observed in connection with the tremendous explosion of volcano Krakatoa in 1883. The great Siberian meteorite of 1938 provided additional data for studies in attempts to correlate observations with theories of pulse propagation. These studies tried to account for the velocity of the pulse, to explain its peculiar signature, to determine the existence of free oscillations of the atmosphere, and to provide any information concerning the structure of the atmosphere.

The interest in this problem has been renewed with the detonation of thermonuclear devices in the atmosphere. These "megaton" class

explosions excite long atmospheric waves and provide data for a world-wide net of sensitive barographs. Since the structure of the atmosphere is sufficiently known from rocket soundings and satellite observations, the major emphasis is now being placed on the use of this reasonably well known atmospheric structure to explain the significant features observed on the barograms. With the advent of the high speed digital computors, numerical solutions can be carried out for a more realistic atmospheric model.

Under AFOSR research grant AF-AFOSR-62-421 to the California Institute of Technology, Professor Frank Press and Dr. David Harkrider have determined the numerical solutions for the problem of wave propagation in which the atmosphere is considered as a two dimensional wave guide. Phase and group velocity dispersion curves, and vertical pressure distributions are numerically evaluated for a number of modes in relationship to the atmospheric structures. Their procedure was to represent the complex vertical temperature structure of the atmosphere by a large number of isothermal layers. The solution to the equation of motion for each layer takes a particularly simple form. Boundary conditions at each interface and the characteristics equation for the multi-layered wave guide are cast into a Haskell matrix formulation. In practice, it was found that 20-40 layers are sufficient to obtain an adequate approximation for the real atmosphere. The conclusion reached from a comparison of theoretical results and experimental data from large thermonuclear explosions using the time and frequency domains are: (1) The major features on the barogram are due to dispersion (2) Superposition of several modes are needed to explain observed features; (3) Scatter of data outside the range permitted by extreme atmospheric models shows influence of winds on the air waves following the long path through the antipodes to the detector.

Future research will include the inhomogeneous problem in which the source and atmospheric excitation functions are considered.



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